United States Air Force
Scientific Advisory Board

Report on

Building the Joint Battlespace Infosphere

Volume 1: Summary

SAB-TR-99-02

December 17, 1999

Cleared for Open Publication – February 2000

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Executive Summary

The Joint Battlespace Infosphere Defined Operationally

The Joint Battlespace Infosphere (JBI) is a combat information management system that provides individual users with the specific information required for their functional responsibilities during crisis or conflict. The JBI integrates data from a wide variety of sources, aggregates this information, and distributes the information in the appropriate form and level of detail to users at all echelons. The JBI was originally described in the 1998 USAF Scientific Advisory Board (SAB) report *Information Management to Support the Warrior*.

At the joint task force (JTF) commander's level, the JBI is a powerful command and control (C^2) system that combines inputs from a variety of sources, including existing C^2 systems, reconnaissance data, satellite data, unit capability data, logistics data, and real-time battlefield conditions. The JBI builds an aggregated picture from these combined inputs, giving unparalleled situational awareness accessed as easily as a web page. The JBI also provides for speedy downward flow of information, so when commanders order an action, the action is received and implemented at the subordinate level almost immediately.

The commander in chief (CINC) or JTF commander creates a JBI for a specific purpose, usually in response to a crisis or conflict. The JBI enables the commander to focus information support for a specific operational purpose, ensure or limit access to critical information, and provide an information management system that can respond to natural or enemy actions that disrupt communications capabilities. As units are assigned to the mission, their information needs are electronically identified, and available information is automatically accessed. Thus, deployed units are ready to fight immediately upon being deployed or assigned.

The Joint Battlespace Infosphere Defined Technically

Supporting these capabilities and forming a foundation of the JBI is a platform of protocols, processes, and common core functions that permit participating applications and organizations to share and exchange critical mission information in a timely manner. It provides uniform rules for publishing new and updated objects into the JBI and promptly alerts any JBI clients that have subscribed to such objects. These properties enable dynamic information flows among client programs of the JBI, serving to integrate the clients to conduct a single mission.

The JBI platform integrates many individual information systems that currently support operational forces. Each existing system has been developed in a stovepiped fashion; few interoperate with each other. The JBI acts as an intermediary between these systems, converting information from one representation to another to enable interoperability. In addition to acting as middleman between disparate systems, the JBI interprets the information flowing between applications, using it to build its own, more complete, picture of the current situation. Furthermore, the JBI tailors this picture for individual users: the commander gets a high-level view of the campaign, while the soldier in the field gets a detailed description of a nearby hostile base.

The JBI provides an architecture for the incorporation of future data capture technologies that exploit better sensors, databases, fusion engines, automated analysis tools, collaborative planning and execution aides, and distribution controls. It is also a disciplined process that guides the activities of people responsible for obtaining, verifying, fusing, presenting, analyzing, and controlling the information necessary for success in any operation.

The Joint Battlespace Infosphere Defined Relative to Present Systems

The JBI is connected to, and interoperable with, a variety of existing and planned C^2 and combat support information systems. The JBI is not intended to replace C^2 systems, but to be the substrate for integrating them. The JBI subscribes to pertinent information published by supporting systems and, when necessary, pulls specific information from other networks. In addition, the JBI connects to fusion engines and may perform fusion on its own, thereby ensuring that the most complete and coherent picture of the battlefield situation resides within the JBI itself. The JBI concept recognizes that display technology is constantly advancing and that new displays must be tailored for users from flight leader to JTF commander.

The JBI provides services through a federation of multiple servers. The Global Information Grid connects these servers to each other and to the many systems that support the JBI. Many of the servers provide services from the rear via reachback, thereby limiting the forward footprint of the JBI.

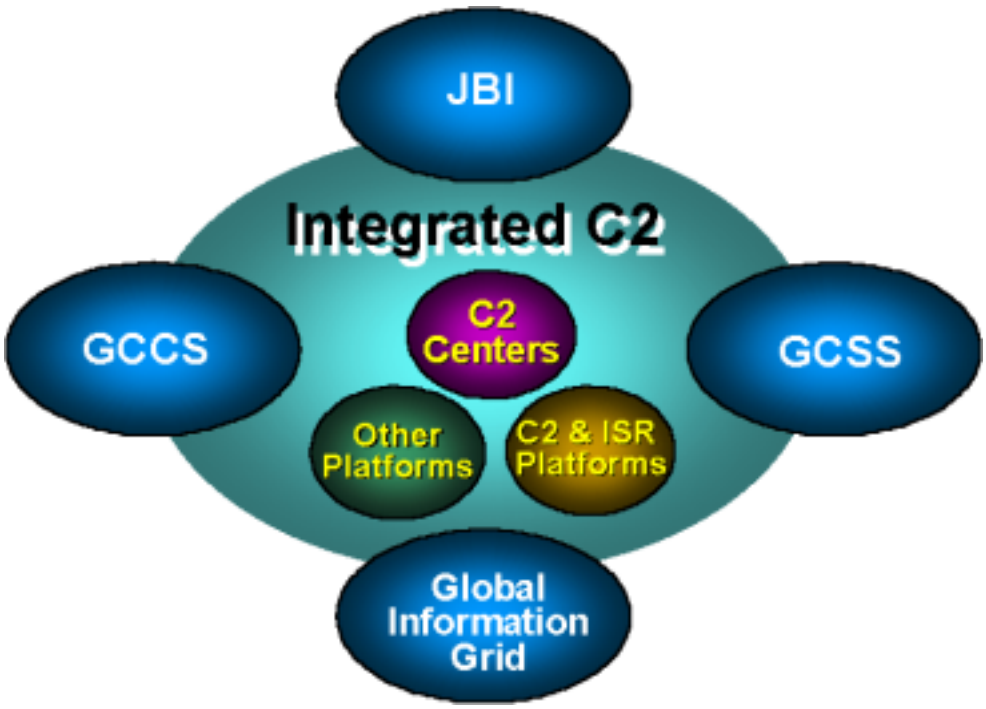

Figure S-1. *The JBI integrates C^2 resources on top of the Global Information Grid infrastructure*

Report Overview

This report provides a brief description of the JBI's capabilities and its operation. The main focus of this report, however, is the technical roadmap for building the JBI. Namely, it answers the questions "What technologies make up the building blocks of the JBI?" "In which technologies should the Department of Defense invest?" and "How should that investment be managed?"

JBI Capabilities

What does the JBI do for the warfighter? First, *warfighter* is defined in the broadest sense, from intelligence analyst to maintenance crewmember to JTF commander. Each warfighter receives exactly the information needed to perform his or her function. Not only is it the right information; it is updated when new information enters the JBI, so that the information delivered is timely and consistent with the information shared with all JBI users. Furthermore, that information is delivered via an appropriate interface: on a soldier's handheld computer, the pilot's head-up display, or the virtual-reality collaborative environment within which many users share information and explore alternative courses of action through simulation.

Not only does the JBI distribute information, it aggregates and fuses information to generate higher-level knowledge. Thus, the joint force commander (JFC) can get an aggregated, or summary, view of the battlespace. The commander can also request more detailed information on a particular topic of concern and the predicted consequences of command decisions. The JBI maintains pedigree information as it aggregates information, so the commander can drill down to examine the inputs and processes the JBI uses to generate an aggregated piece of higher-level knowledge.

In addition to providing information to users at all echelons, the JBI eases system management through automation of critical tasks. The first of these tasks is to stand up the JBI appropriate for the region and mission to be performed. A critical function is the management of units as they are assigned to the JTF. Each deployed unit defines its capabilities, support needs, and information interface (subscription and publish descriptions) through the use of force templates. Force templates define the electronic handshake between the JBI and subordinate units, and their use lets units be quickly added to the JBI with little or no manual reconfiguration required. Another self-management task performed by the JBI is bandwidth management. Specifically, the JBI must ensure that communications links are used efficiently so that information is rerouted or volume reduced when links are down, degraded, overloaded, or compromised.

The JBI also supports management by the JFC's information management staff. This staff can change access controls on information, write scripts (that is, fuselets) to redirect or aggregate information in a new way and to configure gateways between the JBI and coalition information resources.

Because the information staff can change the JBI by writing new fuselets, the JBI is flexible. The JBI serves the JFC and other users in performing their jobs rather than constraining them to perform in fixed, awkward ways. Furthermore, operational processes for working with the JBI

will develop as the JBI is in spiral development, so any system tweaking and tuning needed in a deployed JBI will be minimal.

In sum, the JBI enhances information storage and information flows among the people and computer processes engaged in conducting a military operation. Improved ability to sift and distill information rapidly provides better guidance to the commander, staff, and warfighters of a mission. A mission is configured with the right information-processing resources, both humans and computers, to manage the mission's information and develop useful knowledge from the information. The JBI's role is to store or provide access to sensor information, intermediate results, and ultimate knowledge in a repository so that it can be shared throughout the mission—subject to proper access authorization. The JBI also arranges to route information to the right destinations, alerting the people and processes that should respond to new data. The chain of alerts constitutes a workflow process, designed and adapted to process the mission's information. These JBI mechanisms ensure that the information it provides is an asset to the mission.

JBI Technical Overview

The JBI is built on four key concepts. These are

1. Information exchange through "publish and subscribe"
2. Transforming data into knowledge via fuselets
3. Distributed collaboration through shared, updateable knowledge objects
4. Assigned unit incorporation via force templates

The next sections describe the use of these technologies in the JBI implementation.

Information Exchange Through Publish and Subscribe

Users and programs *subscribe* to information of interest in the JBI. Each piece of information is stored in the JBI as an *object*. Objects contain both the represented information and metadata (that is, data about data) describing the information. Subscriptions contain search values for metadata fields. When a new object is published in the JBI, any subscriptions matched by the object's metadata are fulfilled. That is, the subscriber receives the new information. If the subscriber is a user, the user receives an immediate notification of the new information. The form of the new information depends on the user, the application program, and the computing device being used. For example, the JBI may overlay a new graphic on a 2-D map image, or change the list of weapons to be loaded on an F/A-18, or sound an audible alarm in conjunction with flashing red visuals on a cathode ray tube. The next section describes the situation when a program subscribes to information.

Transforming Data Into Knowledge Via Fuselets

Programs subscribing to information in the JBI are called *fuselets*. When information becomes available to a fuselet via a subscription, the fuselet publishes one or more new objects as a result. Fuselets can be used to encode a commander's standing orders, such as "if a tactical ballistic missile launch is detected, issue a 'major threat' alert." Fuselets may also be used to provide regular reports that summarize information, for example, weapon inventories and sortie counts. The JBI includes a library of fuselets to cover anticipated situations, and the information

management staff may write more fuselets using a scripting language. While fuselets can act on certain conditions, they are based on rules and do not themselves exhibit common sense or judgment when executing. However, fuselets may submit requests to more robust and complicated fusion engines that apply reasoning to the input data. Eventually users may implement fuselets for specific purposes by dragging and dropping an icon to carry out specific functions.

Distributed Collaboration Through Shared, Updateable Knowledge Objects

Users interact with the JBI in many ways. Behind these interaction modes is a set of information objects describing the common operating picture. When new data or information arrive in the JBI, subscribers receive the appropriate direct information or as derived through the use of fuselets. For example, a command center user may have a 3-D virtual reality environment modeling the entire battlespace. A soldier in the field may have a personal digital assistant. If the soldier in the field reports the presence of an artillery battery, the user in the command center may see the battery instantly in the virtual reality model. Similarly, the JBI supports collaborative planning using the "shared whiteboard" notion—that is, collaborative tools let multiple users interact with an application, see changes made by other users, and ultimately come to agreement on the final product.

Unit Incorporation Via Force Templates

The force template is a software description of a military unit that may be integrated into a JTF. Several varieties of force templates are used. One form of force template describes a fighting unit (for example, a tank battalion or fighter squadron). The key elements of information included in such a force template include force employment capability, ammunition inventory, fuel requirements, communications requirements, computing systems, information requirements (the unit's clients' subscriptions), information products (objects to publish both during instantiation and later)—for example, intelligence, surveillance, and reconnaissance (ISR), and personnel requirements. Another variety of force template is one describing a support unit. A template for these units always includes information requirements (the unit's clients' subscriptions), information products (objects to publish), communications requirements, and computing systems. However, the specific publish and subscribe exchange described in the force template varies depending on the type of unit. For example, an airlift control unit force template would agree to publish information about the locations and movement of relevant airlift assets while subscribing to airlift needs generated by the JBI.

Technical Infrastructure

Other technologies support the JBI as well. These are briefly described in this section.

Browsing. JBI users browse through the JBI, much the way they browse the Web today. The browser is able to fetch objects from the JBI, to search the JBI using queries, and to make visual presentations of many of the common JBI information objects. A browser may also include tools for creating objects, which then are published to the JBI.

Interaction. Many clients are designed to connect humans to JBI information in special ways. For example, a mission rehearsal client might query the JBI to obtain details of a mission and then build a 3-D fly-through environment in which a pilot can rehearse the mission.

Fusion. One of the missions of the JBI is to fuse information from a variety of sources into high-level "knowledge" that is readily accessible to the commander and other staff. Fusion programs designed to take advantage of the JBI's information exchange capabilities can subscribe to information from many different sources. If the information is available, the fusion program is informed via the subscription, and the program can fuse the information. In other words, fusion programs can now be written to take advantage of any available information they can understand and evaluate.

Objects. The JBI information objects are like extensible markup language (XML™) documents, instead of objects in the sense of object-oriented programming. Every JBI object is an instance of an object schema. The object schema defines and abstracts a category of things using <attribute, value> pairs. Object schemas are stored in the JBI. Client programs are able to query the JBI to discover the existence of an object class that may satisfy their information needs. Object metadata attributes describe the JBI object rather than the real-world object represented by the object. The metadata values support querying and subscriptions.

Structured common representation. Objects in the JBI are related to each other. The objects and their relationships form a representation of the current military situation. These object relationships are stored in a structured common representation (SCR), which describe hierarchical relationships as well as more *ad hoc* relationships. The SCR supports presentation and tailoring of information. It also supports drill down through hierarchies of knowledge, so the user is able to examine evidence supporting presented information.

Automatic data capture. As users interact with the JBI, the interface used is natural for their duties, locations, and types of devices. Voice recognition technology is an obvious step from keyboarding to a more natural interface. As technology matures, the interface could infer information from both the user's voice and gestures, so that when a user points at a display and says, "There," the system could infer the intended location.

Tailoring information to meet user needs. The understanding of a situation or the available options depends critically on presenting the information in an appropriate form. The presentation format exploits multimodal sensor input from a combination of visual, aural, and haptic interfaces. Geospatially referenced presentations, 3-D graphics, animation, image zoom, and moving forward and backward in time are some of the tools that are available. But the presentations must be tailored to the workflow task and to the preferences of a particular user. What is presented in the cockpit may be very different from what is presented in a command center.

Implementation Possibilities

The JBI implementation will not result in a monolithic, single-paradigm program. Instead, it will use different approaches to provide different services. The most promising candidates for the JBI architecture from today's technologies are listed below.

Digital libraries. A digital library consists of multiple repositories responsible for storing digital objects. Digital libraries include *index servers* to answer queries and searches, while *handle servers* provide a cross-reference between objects and the repositories in which they reside.

Enterprise integration technologies. This is a class of middleware techniques used to integrate otherwise separate (that is, stovepiped) business information technology applications. Generally, they use software "connectors" to provide a linkage between each application and a shared structure for communicating information from one application to another.

XML technologies. XML is a hypertext markup language (HTML) successor. XML provides a way to describe data structures in a textual form. It can be used to represent JBI object schemas and objects. Furthermore, commercial interest in XML has led to commercial-off-the-shelf (COTS) XML tools that are proliferating even now.

A Development Roadmap

The core recommendations resulting from this study are

- Immediately fund concept validation prototypes. Each partially complete prototype (YJBI) will employ an object-based common representation. Each will include an object repository and object-based force templates. Low-cost experimental prototypes will demonstrate a service, such as publishing information from a YJBI client[1] to the object repository. YJBI experiments should make heavy use of commercial products, even if these may include products inappropriate for later operational designs for reasons of security or other factors.
- Initiate a information management cadre to work operational business processes as part of the YJBI development.
- Support or reallocate funding for research programs within Service laboratories and the Defense Advanced Research Projects Agency (DARPA) to support advanced JBI platform concepts. These include issues such as common representation, military information assurance, and information fusion.
- Initiate spiral development of an operational JBI. Initiation should occur after designers and warfighters agree on functionality, and after YJBI concept validations have established credibility.

  The study team recommends that the concept validation and early spiral development be based heavily on web technology. In the Department of Defense (DoD), developmental vectors for many C^2 systems are realigning toward the web. In addition, other commercial products must be evaluated for possible deployment in the JBI, and they should be included as early as possible during spiral development.

[1] A JBI client is any software application that makes use of JBI platform services to publish, subscribe, or otherwise interact with JBI information objects.

- Development of the long-term JBI architecture should not impede rapid development of prototypes, since early prototypes are crucial to the warfighter and provide architectural validations. Similarly, the youthful state of the art in information assurance should not slow the development of the JBI. DARPA and others have large research efforts in information assurance. Rapid prototypes need only exhibit partial coverage of JBI core platform services: a skeletal common representation, at least one C^2 client application exhibiting publish and subscribe, and an interaction capability. Rapid prototypes should be designed to clarify the vision of USAF warfighters, joint-Service users, and C^2 system design specialists. The focus of these first JBI prototypes should be firmly on *inexpensive evaluation and idea generation*. Architecture studies conducted in parallel should focus on downstream functionality for spiral development. While early prototypes provide early concept validation and feedback, long-term research must be supported to provide critical capabilities in later stages of spiral development.

Finally, the spiral development of the JBI must go hand in hand with development of the information staff, both professionally and technically, and with the development of the JBI business processes. The C^2 business processes are tightly linked to the information systems in use. These business processes must evolve in spirals with the JBI. In addition, new business processes should be evaluated using process models, data models, workflow models, and simulation models.

The JBI Roadmap

The JBI study team created a roadmap for development and phased improvement in the format of major weapon systems. The roadmap serves as a programming guideline and is summarized below.

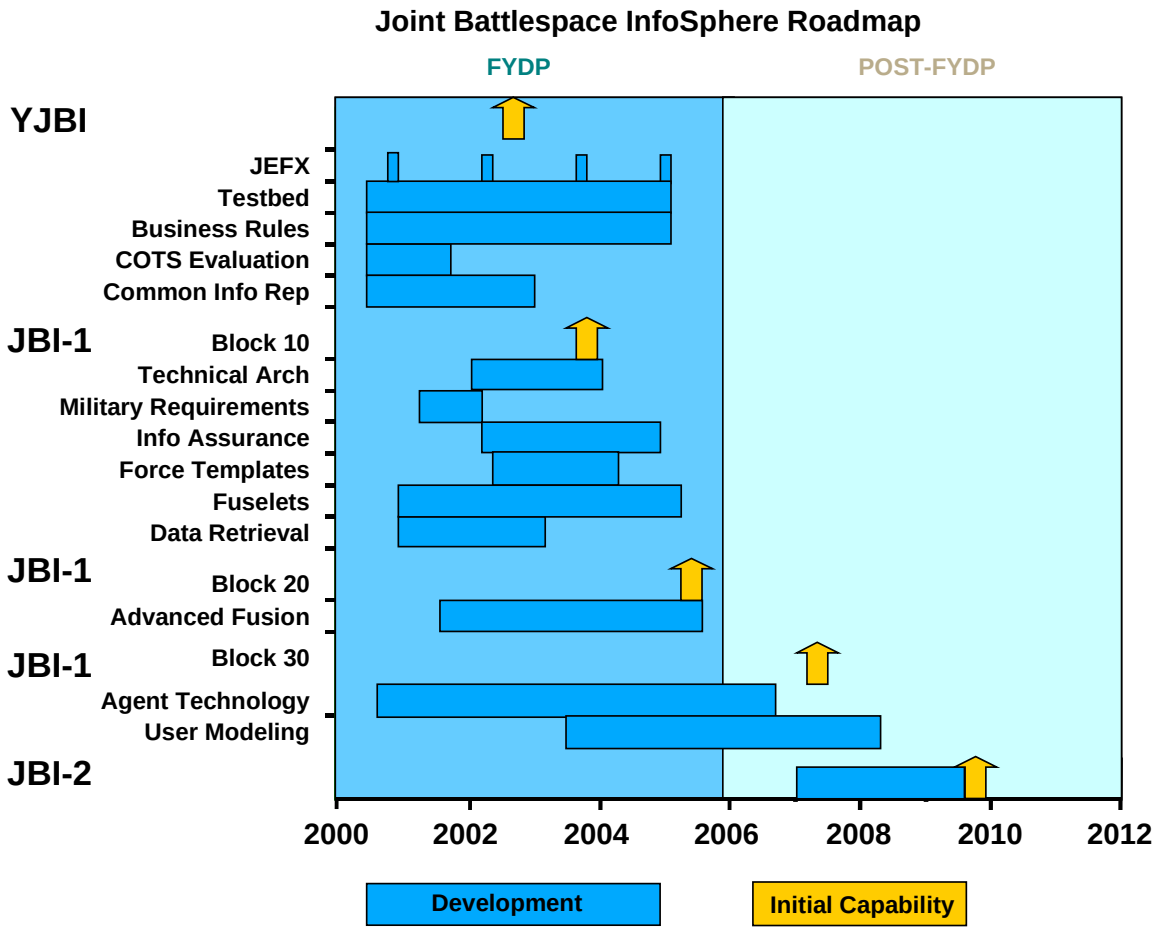

Figure S-2. *JBI development roadmap*

Executable Recommendations

To ensure that the JBI goes from the vision described herein to reality, the JBI must be considered a major weapon system. In that light, this study makes the following additional recommendations relating to the management of the JBI:

- Create an information staff function
- Develop new concepts of operations at the Aerospace Command and Control Intelligence, Surveillance, and Reconnaissance Center (AC^2ISRC)
- Define common information representations led by the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (ASD-C^3I)
- Reinforce DARPA research and development (R&D) investment for JBI technologies
- Focus the Air Force Research Laboratory (AFRL), other Service research labs, and battlelabs on evaluating and applying commercial technologies for the JBI
- Create the JBI testbed now for Joint Expeditionary Force Experiment 00 participation
- Link the JBI testbed to other Service efforts in digitized battlefield and network-centric warfare
- Promote the JBI to the CINCs

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